ISRJ ONLINE
INTERNATIONAL SCIENCE RESEARCH JOURNAL
ISSN: 2006-1730

GIS IN MANAGEMENT OF WATER DISTRIBUTION NETWORK OF ONITSHA-NORTH L.G.A., ANAMBRA STATE, NIGERIA

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ABSTRACT: The paper presents the use of Geographic Information System (GIS) in Management of Water Distribution Facilities. With inherent limitations faced by traditional system of keeping and managing information, an automated system is developed for Water Board in Onitsha-North L.G.A., Anambra State, Nigeria. The administrative/street and water distribution network maps were collected from relevant agencies. Water distribution facilities spatial database was designed and created using relational database model approach. The paper maps were converted to digital form, through scanning process using A3 scanner with photo-plus. The raster images were sent to AutoCAD Map R_2 environment for geo-referencing and on-screen vectorization. The drawings were edited and exported to ArcView 3.2a environment for analysis. The graphics were linked with the created spatial database. The developed system was put to performance test by carrying out a number of GIS operations. Results obtained were displayed in graphics and tables and showed spatial locations of some water distribution features such as water pipelines. The locations of all existing water pipelines with dimension 150mm were also shown. The study suggests that GIS is a competent and effective tool for managing water distribution network. Thus, it is recommended that awareness be created including training and retraining of staff of Water Boards and other municipal authorities on GIS and its applications in management of water distribution network.

KEY WORDS: GIS Application, Management of Water, Utility, Distribution Network

INTRODUCTION

Water is an essential commodity, which is important to living things. Water is considered to play a very crucial role in human survival, as it is known to be the highest constituent of human body. It therefore becomes one of the most basic needs of man. Lawal (2002), noted that water supply is one of the most important public infrastructure services being provided by government. A breakdown of the services provided by these networks can endanger the life of a society. Efficient functioning and distribution of these services, undoubtedly becomes of paramount importance.

Efficient functioning and distribution of this resource cannot be achieved except timely and accurate decisions/policies are taken towards realizing this goal. On the other hand, timely and accurate decision/policies cannot be taken unless timely and accurate information is provided, hence, Geographic Information System (GIS). Burrough and McDonnell (1998), defined GIS as a "set of tools that collect, store, retrieve, transform and display spatial data from the real world for a particular set of purpose". According to Adeoye (1998), GIS is a configuration of hardware, software, communication networks and analytical procedures for the extraction of information from data to support decision-making so as to achieve planning or managerial objectives.

Any organization that expects to run an efficient day-to-day operation, manage and develop its services effectively must know what assets it has, where they are, their condition, how they are performing, and how much it costs to provide the service (Pickering *et al.*, 1993). Knowledge about physical assets of the enterprise is essential to make strategic and operation decisions. Such knowledge, which can best be provided with GIS, contributes also to the operation and maintenance of assets and to the sensible planning of extensions and new works.

Uluocha (1998) stated that if the noble objective of mapping for proper design and maintenance is to be satisfactorily achieved, the more sophisticated computer-based Automated Mapping/Facility Management (AM/FM) or a GIS must be embraced. With the use of GIS, Water Boards can collect, input, edit, store, retrieve, query, process, analyse and output large amount of data easier and faster at desired scales and projections. Thus, the reason for this study was to create a prototype GIS based water distribution network of Onitsha-North L.G.A., Anambra State, Nigeria. The primary objective was to convert the analogue water utility map to digital and to perform several spatial and aspatial analysis in order to test the developed system.

THE STUDY AREA

The study area (Fig. 1) is Onitsha-North Local Government Area with headquarters at Onitsha in Anambra State, Nigeria. It is situated between latitudes $06^0\ 02^1$ N and $06^0\ 08^1$N and longitudes $06^0\ 47^1$E and $06^0\ 59^1$E. It serves as the gateway between southeastern and southwestern Nigeria. Idemili-North L.G.A., bound the area in the East, in the west by River Niger, in the south by Onitsha-South L.G.A., and in the North by Oyi and Anambra-East L.G.A.

The area situates where a high ground underlain by the sandstones of the Bende-Ameke formation, comes very close to River Niger. It provides a stretch of well-drained, healthy site in the flood plains of the River Niger. Such favorable site at the meeting point of two contrasting regions east and west of the Niger, and the Niger itself, which provides a link with the savanna zone to the north and the forest and delta region to the south, enabled the area to develop as an important commercial center.

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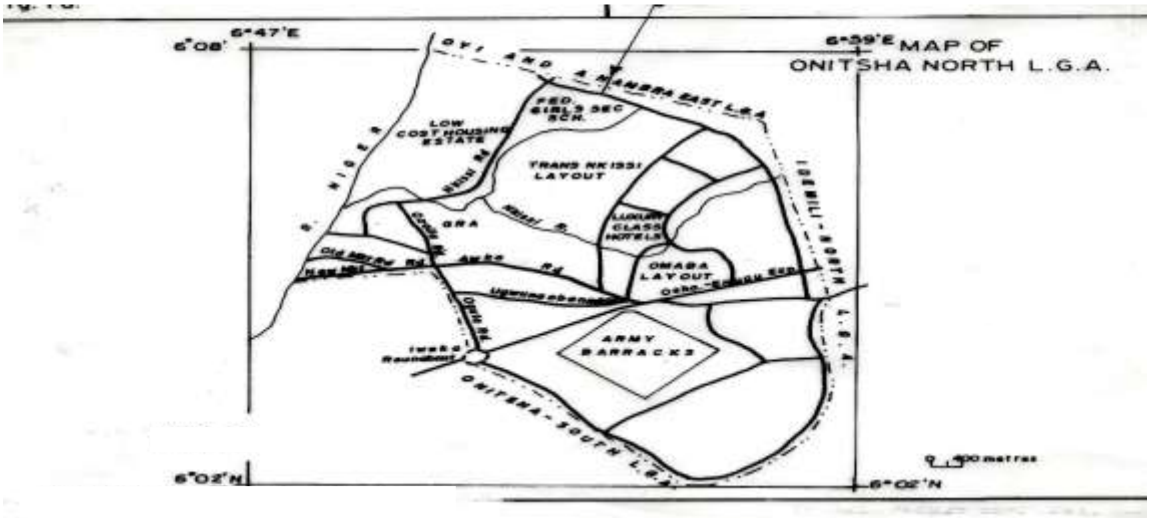

Figure 1 Map of Onitsha-North L.G.A.

For the purpose of administration, the area is divided into 15 wards with the following sub-units: Omagba, Inland town, G.R.A, Ogbe-Umu Onitsha/Otu), American Quarters and Army Barracks. The area is predominated by petty traders and middle-income class earners. People from formal sectors are also found there, exerting some levels of impact on the environment. The people rely mostly on roads and river Niger as means of transportation.

METHODOLOGY

The data sets used include the administrative/street map, the water distribution network map; attribute data and data on the end-users. The administrative/street map was collected from the Anambra State Ministry of Lands, Survey and Urban Planning, Awka. The water distribution network map and some of the attribute data were collected from the Anambra State Water Corporation (ASWC), Onitsha. More of the attribute data and data on the end-users were collected by on-spot observation and personal interview.

A number of application software packages were used for data processing. These include: photo-plus for scanning and Auto CAD map R_2 for geo-referencing and on-screen digitizing. ArcView 3.2a was used for GIS overlay operations and spatial and aspatial analysis.

USER-REQUIRMENT SURVEY

Essentially, user-requirement survey was carried out in order to determine what the end-users would want the system to do for them. This helps to know exactly the type of analysis to be carried out. It also provided a guide for determining the configuration of hardware and software systems required and in choosing the appropriate model and structure to be applied. Other possible benefits that could be derived from good user-requirement survey were noted by Kufoniyi (1998).

DESIGN OF DATABASE

Four basic steps were taken during the design of database. These include articulation of reality, translation of reality to conceptual model, translation of conceptual model to logical design and physical design. Realities were articulated based on the geographic data within the study area with respect to water distribution facilities. In this case, realities include geographic features such as administrative areas, roads, streets, river, mains, existing pipelines, valves and boreholes.

In translation of reality to conceptual model, the articulated realties were represented in a simplified manner and at the same time satisfied the information required by the users. Hence, vector data modeling was adopted. The realities were represented and displayed as points, lines or area (polygon) as the case may be. Their attributes were defined by pair of plane coordinates (X, Y). The objects and their spatial relationships were carefully identified and analysed as given in Entity-Relationship diagram shown in figure 2.

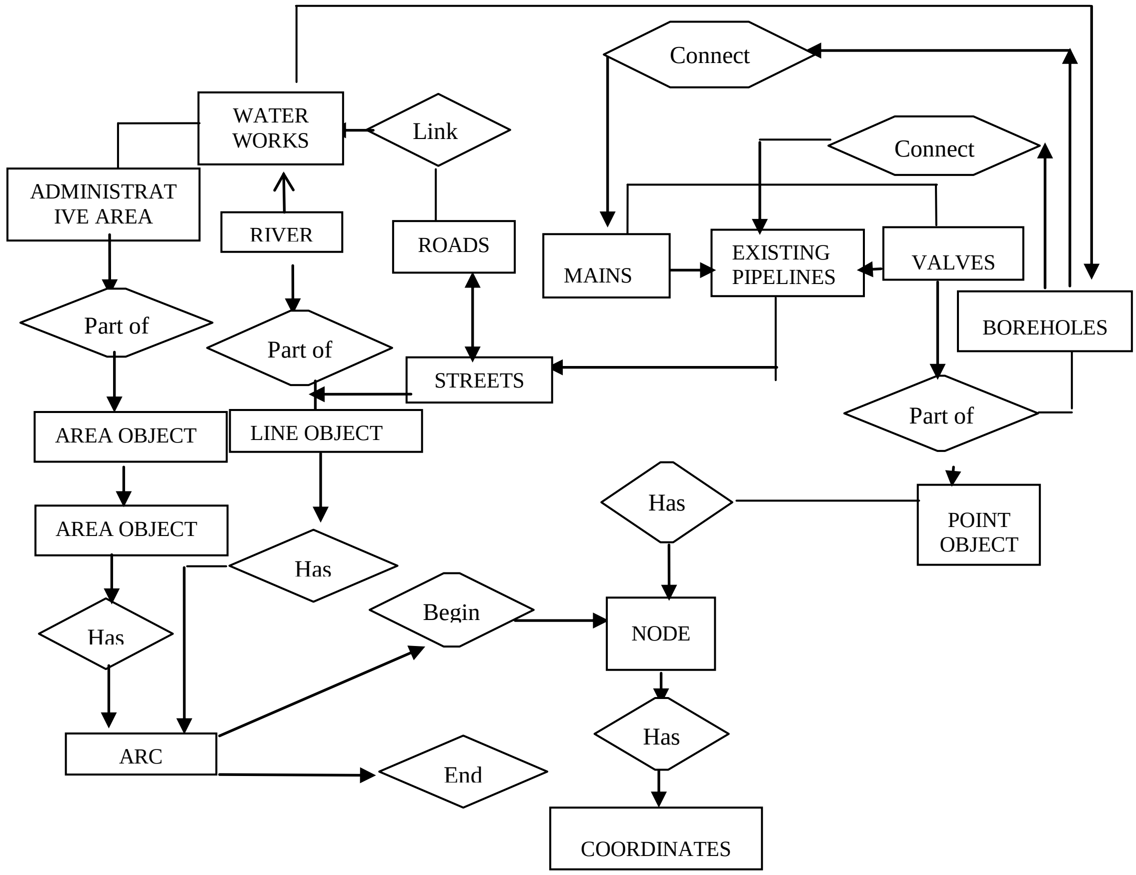

Figure 2 Entity-Relationship Diagram of Onitsha North L.G.A. Water Distribution Network.

Translation of conceptual model to logical design involves representation of the designed data model to reflect the recording of the data in the computer. The data were structured to describe logically the organisation of data in the database. Relational data structure was chosen to implement the model because of its flexibility, capability and very wide deployment both within and outside GIS. The relations derived are as follows:

ADMINISTRATIVE AREA (AD.A _ id)
ROADS (RD_ id; RD _ name; N_Surface; R_class)
STREETS (ST_id; ST_name; N_ surface)
RIVER (R_id; R _ name)
MAINS (M_id; M_capa; M_diam (mm); L_span; Yr_laid; Yr_replaced;
M_type; M_depth (m); M_Loc
EXISTING PIPELINE (EP_ id; EP_ type; EP_Capa; EP _ diam (mm);
EP_Loc; Pop; L_span; Yr_laid; Yr_replaced; EP_ depth (m)
VALVE (V_id; V_name; V_Loc; EP_contr.; M_contr;)
BOREHOLE (B_id; B_Loc; B_depth (m))

During physical design, the designed data structure was represented in a form that is acceptable to the implementation hardware and software. The table names, the attributes, data type, and the width of the data were specified in data declaration as shown in Table 3.0.

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TABLE 3: Data Declaration

TABLE NAME	ATTRIBUTES	DESCRIPTION	DATA TYPE	WIDTH
ADMIN. AREA				
	AD.A_id	Administrative Area identifier	Number	5
	AD.A_Loc	Place where the Administrative Area is located	String	20
ROADS	RD_id	Road identifier	Number	5
	RD_name	The name of the road	String	20
	N_Surface	The nature of the road's surface	String	15
	R_Class	The class in which the road belongs	String	15
STREETS	St_id	Street identifier	Number	5
	St_name	The name of the Street	String	20
	N_Surface	The nature of the Street's surface	String	15
RIVER	R_id	River identifier	Number	5
	R_name	The name of the River	String	10
MAINS	M_id	Main identifier	Number	5
	M_capa	The Capacity of the Main	Number	6
	M_dia (mm)	The diameter of the Main in millimeter	Number	6
	L _ Span (Yrs)	The life span of the Main in years	Number	5
	M_type	The type of material the Main is made of.	String	10
	M _depth (m)	The depth of the Main underground in metres.	Number	5
	Yr_ laid	The year the Main was replaced last.	Number	5
	M_Loc	Place where the Main is located.	String	20
EXISTING PIPELINE	EP_id	Existing pipeline identifier.	Number	5
	EP_Type	The type of material the pipeline is made of.	String	10
	EP_Capa	The capacity of the existing pipeline	Number	6
	EP_dia (mm)	The diameter of the existing pipeline in millimeter.	Number	6
	EP_Loc	Place where the existing pipeline is located.	String	20
	L_Span (Yr.)	The life span of the existing pipeline in years.	Number	5
	Yr_laid	The year the pipeline was laid.	Number	5
	Yr_replaced	The year the pipeline was replaced last.	Number	5
	EP_depth (m)	The depth of the existing pipeline underground in metres.	Number	5
	Population	The no. of people the pipeline is serving.	Number	10
	A_served	The area the pipeline is serving	String	20
VALVE	V_id	Valve identifier	Number	5
	V_name	The name of the Valve	String	16
	V__Loc	The place where the Valve is located.		
	EP I_Cont	Identifier of the existing pipeline, the valve is controlling	Number	5
BOREHOLE	B_id	Borehole identifier	Number	5
	B_Loc	The place where the borehole is located.	String	20
	B_depth (m)	The depth of the borehole in metres.	Number	5

SYSTEM SELECTION

The following hardware and software systems were used: Stand-alone (PCs) hardware platform (with configuration: 4GB of RAM; 500GB of hard disk; Windows 7); 15" colour and graphic monitor; A3 scanner, DeskJet 1210C printer; Photo-plus; AutoCAD map R_2 and ArcView 3.2a.

CREATION OF DATABASE

The database was created by inputting the relevant spatial and attribute data into the system. The tables were populated with the attribute data. The spatial data were captured by scanning the paper maps using A3 scanner with photo-plus. The raster images were geo-referenced and digitized on-screen in AutoCAD map R_2 environment. The images were separated and digitized under the following layers:

(i) Base map: administrative areas, roads, streets, and river

(ii) Water distribution network: mains, existing pipelines, valves, boreholes

QUALITY ASSURANCE AND QUALITY CONTROL

The digitized drawings were edited and subjected to quality assurance test. The edited drawings (See figures 3.0 and 4.0) were exported to Arc View 3.2a environment and linked with the created database after converting them to shape files. The linkage was possible by assigning unique identifiers to each of the entities. Then, GIS operations and analysis were carried out.

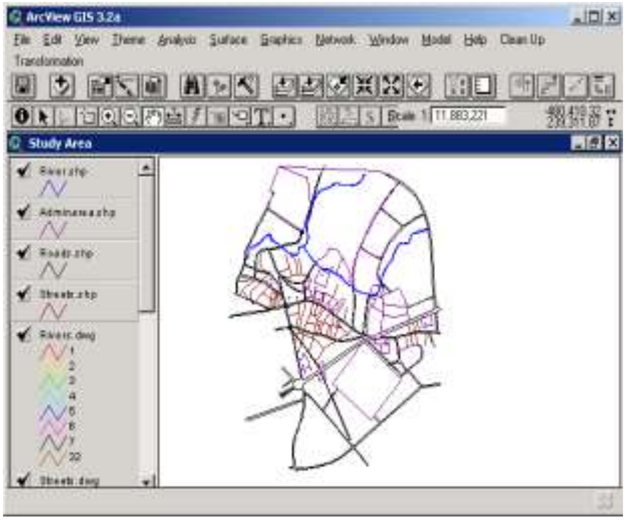

Figure 3.0 Digitized and edited drawings of Administrative/street map of Onitsha-North L.G.A.

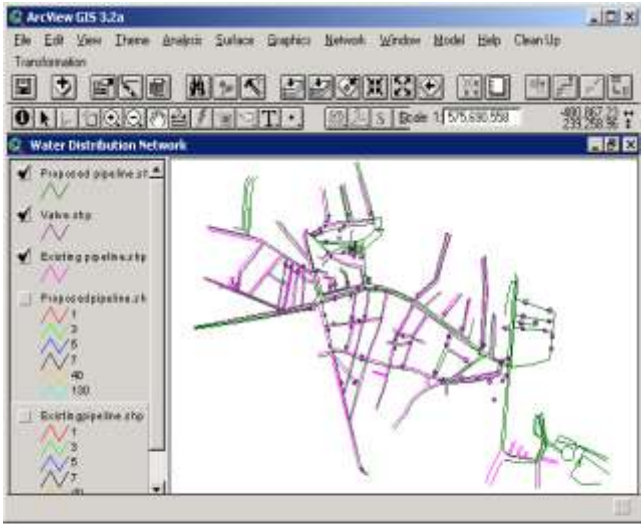

Figure 4.0 Digitized and edited drawings of Onitsha-North water distribution network

DATA ANALYSIS AND PRESENTATION

GIS operations and analysis that were performed include overlay operation, spatial query, and aspatial query.

OVERLAY OPERATION

The essence of overlay operation was to superimpose two or more data layers that occupy the same location (Sun *et al.*, 2001). The base map was superimposed with the water distribution network. The result of the overlay operation is shown in figure 5.0.

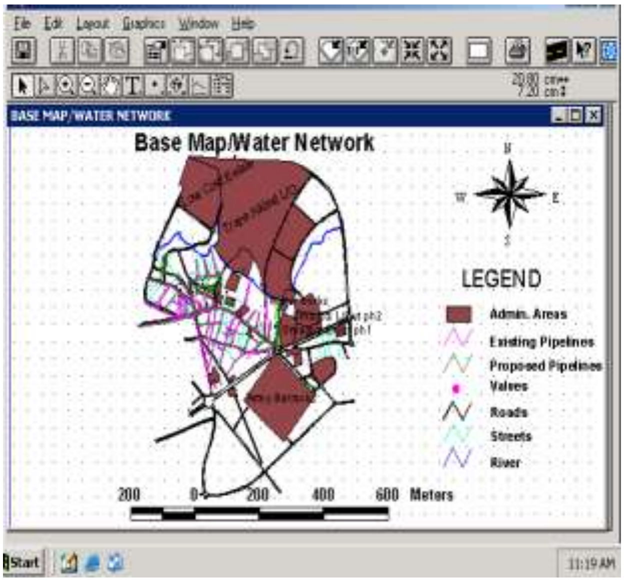

Figure 5.0 Map of Onitsha-North L.G.A. overlaid with water distribution network

SPATIAL QUERY

Spatial query was carried out to get all information about a particular water distribution facility located in an area. In this case, the system was queried to search and display all available information about the existing water pipeline located

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along Oguta Road. The result was displayed as shown in figure 6.0.

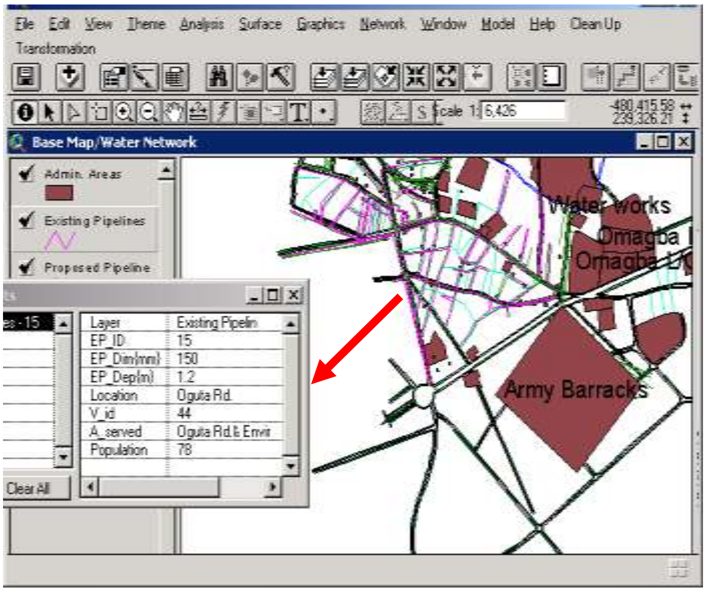

Figure 6.0 An existing water pipeline along Oguta road with its attribute information.

ASPATIAL QUERY

This task was carried out in order to determine the location(s) of a given facility with a known attribute. For example, the location(s) of all the existing water pipelines with dimension 150mm could be known as provided by the system. The result is shown in figure 7.0.

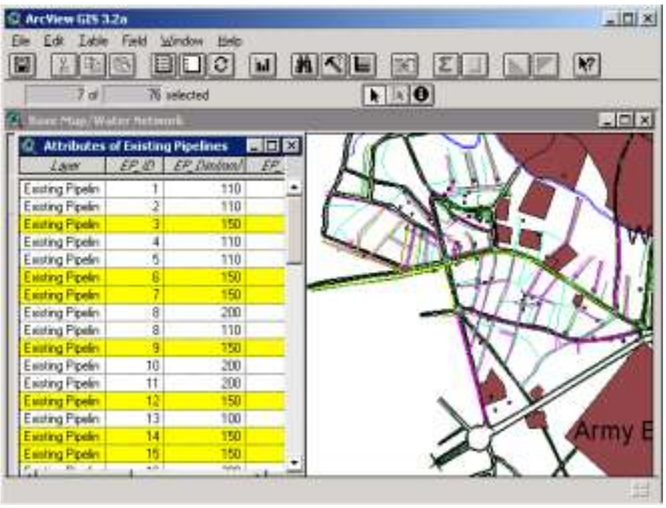

Figure 7.0 The locations of all the existing water pipelines with dimension 150mm.

DISCUSSIONS

In figure 5.0, the base map was overlaid with the water distribution network, hence revealing the spatial distributions and locations of water facilities. The facilities on ground such as water valves, existing pipelines, proposed pipelines, etc, were shown and the extents at which they occur were also revealed. This result can help the Water Board in knowing the spatial relationships that exist among their facilities. Such knowledge will help them determine the area(s) or section(s) of the town that lack their water supply. It will also guide them in knowing where they could extend or improve their services and areas that may need new installation.

In addition to these, the results can equally provide good information for other professionals, for example Urban Planners, Construction Managers, Civil Engineers etc. The knowledge of the spatial locations of the water distribution faculties will help to avoid or reduce damages done to these faculties during construction works. To the town planners, it will help to plan better. When damages occur in any of the faculties, GIS will assist in quick location of problem areas and best approach to solution. Overlay operation can be used during map revision and up-dating GIS environment and in identification of changes due to time in a given area.

The result in figure 6.0 revealed the attribute information of the selected object, which is shown with an arrow pointing at it. The identified results table displayed, shows descriptive information about the object. The object is an existing water pipeline with dimension 150mm. The depth at which the pipeline was buried underground is 1.2m and it is located along Oguta road. It has a Valve with "id" 44. The pipeline is serving population of 78, all within Oguta road and its environs. In figure 7.0, the polylines shown in yellow colour are the selected existing water pipelines of dimension 150mm. Their associated records are also highlighted in yellow colour on the existing pipeline table.

The study has demonstrated the capabilities of GIS in handling and managing water distribution spatial data. With GIS, it is possible to manipulate and carry out tasks that are vital in the management of water distribution services for proper and efficient results. When new facilities are laid, the GIS database and graphical components can be updated easily to accommodate the new features. Thus, map revision and digital mapping can be a lot easy using GIS.

MORE BENEFITS OF THE DEVELOPED SYSTEM

Additional benefits that can be derived from the developed system are as follows:

(i) It can aid the Water Board and other utility companies such as NEPA, NITEL etc, to have knowledge of the assets that they have, where they are, their conditions and their performance.
(ii) The system can also help them to assess deficiencies and to engage in forward planning.
(iii) Back-up system can easily be provided which can help to avoid data loss.
(iv) There will be easy and speedy retrieval of information and due to the flexibility of the system; data up-date and editing can easily be achieved.
(v) The system allows for simultaneous data sharing among various users of the organization.

CONCLUSIONS

With GIS, spatial and attribute data of water distribution network of Onitsha-North L.G.A, which are presently acquired, processed, managed, stored, and presented in analogue form, can be converted to digital. Digital system provides timely, accurate, and easier way of acquiring information, which is vital in taken prompt and accurate decisions necessary in the economic development of any enterprise. Ayeni *et al*. (2003) noted that Geospatial Information is essential to economic planning and national development. This was buttressed further by Alamu, and Ejiobih (2002), who concluded that a well maintained utility information infrastructure can provide an up to-date information about "what is where", "the condition", "the result of other actions on it" and "how it can be harnessed for optimum use of the people and economy".

Having demonstrated the potential of GIS for better management of water distributions network, the following recommendations are proffered:

(i) There is need for greater awareness to be created at all levels of government. Starting from national level through the municipal, down to individual managers, in Water Boards of what is required to establish GIS.
(ii) The Water Boards as well as other organizations that have dealings with spatial data should embrace the digital system of keeping and managing spatial data.
(iii) There is need for GIS briefings, training and re-training sessions among staff of Water Boards and other municipal authorities.
(iv) The services of Geomaticians are needed in Water Boards. They will champion the responsibility of spatial data acquisition, processing, management and presentation of outputs in usable form.
(v) Good institutional framework should be established at all levels of governments down to individuals who will be coordinating the affairs of producers and users of geo-spatial data.
(vi) A legal framework addressing the issue of spatial data compatibility through establishment of, for example, map scales, location referencing, and standard symbols etc should be provided.

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